

## Application of the wirebonding technology in the hot wire anemometry

M. Búran, M. Řezníček

Department of Microelectronics, The Faculty of Electrical Engineering and Communication,  
Brno University of Technology, Technická 3058/10, 616 00 Brno, Czech Republic

E-mail: xburan02@stud.feec.vutbr.cz

### Annotation:

The study deals with the possibility of using wire-bonding technology in hot-wire anemometry. In general, anemometry deals with measuring the velocity and the direction of flow. In the case of hot-wire anemometry, the sensors with hot wire. In this work are inscribed information about design, construction realization of the experimental sensor and verification of its basic properties. The measurement was performed to the temperature up to 300 °C. The basis of the construction solution is using of the heatproof and stable materials.

### Anotace:

Studie se zabývá možným využitím technologie kontaktování v oblasti žárové anemometrie. Obecně se anemometrie věnuje měření rychlosti a směru proudění. V případě žárové (termické) anemometrie je senzorem žhavený drát. V této práci jsou uvedeny informace o návrhu, realizaci konstrukce experimentálního senzoru a ověření jeho základních vlastností při měření v prostředí až do 300 °C. Základem konstrukčního řešení je použití tepelně odolných a stabilních materiálů.

## INTRODUCTION

The Anemometry for measurement purposes uses various types of sensors and specialized equipment. Specialized instruments and sensors working on mechanical, aerodynamical and/or acoustic principles are used for such measurements. In the case of hot-wire anemometry, are used the sensors with hot wire. When is the hot wire sensor heated to a high temperature, its resistance increase. The air flowing in the wire's proximity cools the wire by its movement, thereby changing its electrical properties. It causes to a decrease in electrical resistance. These electrical properties change is then evaluated as the flow rate. [1],[2]

## MOTIVATION

The main motivation of the work is the realization of the own construction of the hot wire anemometry sensor. Wire-bonding technology is commonly used to make an electrical connections between semiconductor chips and lead frames. This technology was used to make the hot-wire anemometry sensor. Changes in experimental design include the using of resistant materials. One of the main purposes is also using the sensor in the environment with high temperatures and the environment with corrosive substances. The existing sensors are not intended for such conditions or their cost is disproportionately expensive.

## CONSTRUCTION DESIGN

For sensor design in elevated ambient temperature applications, it is necessary to consider materials that can withstand the conditions of that environment.

The basic material considered for the construction is ceramic  $Al_2O_3$  which is very hard, heatproof and heat conductive. (Fig. 1) [5].

Advantage of the ceramic material is also chemical resistance. Another important element of the construction is micro-wire carriers. The microwire will have later a major sensory function. The simplest and most affordable solution is to use gold-plated connector pins. The method of mounting the micro-wire on the structure is also important and is crucial for the correct functionality of the sensor.



Figure 2 Original idea of the design

## SENSOR MANUFACTURING

The base of the sensor frame is a ceramic substrate of 25.4x25.4 mm with square shape. As a holder of gold-plated pins is used a ceramic cavity. That is made of the same material as the square base. The gold

microwire is located on the top of the gold plated pins. The ceramic cavity also serves for measuring wires. All ceramic parts of the structure are glued together using a thermally conductive adhesive Polytec TC430 (Fig. 2). The adhesive is sufficiently resistant against thermal and mechanical operating conditions of the environment. The destructive mechanical test did not damage the glued joint. The test caused in the rupture of the ceramic above the glued joint. Alternatively, it is possible to use liquid glass or liquid ceramic followed by firing as a binder. However, such a process is technologically and time difficult.

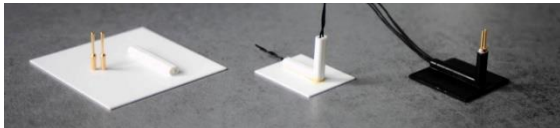


Figure 2 Production process

The wires with Teflon insulation provide the measuring signal lines. They are sufficiently resistant for use up to 300 ° C. The ends of the wires were connected to the connector pins using a braze. After making this joint, the pins with the wires were inserted together into the ceramic structure and they were fixed with Polytec TC430 adhesive. The ceramics were then coated with a silicone-based protective coating.

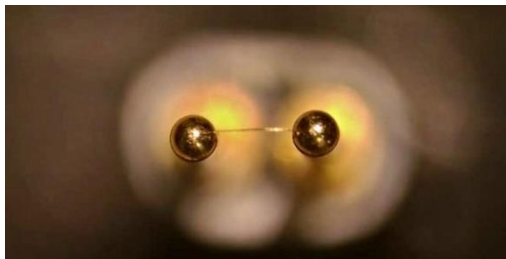


Figure 3 Detail of gold wire

The wire-bonding is realized using the ultrasonic method with optimized parameters, especially for the surface of the gold-plated pins (Fig. 3). Neither thermo-compression nor thermosonic methods are suitable for this application due to the shape of the wirebonded loop and increased dissipation of heat energy in the ball joint area. [4]

The microwire connection between the pins has a length of 2.5 mm and is realized in the form of low loop resp. zero loop. The low loop connection is a special ultrasonic wire-bonding method for construction the loop with minimal height. The minimum bending of the wire and its maximum possible flatness are important for the quality of the directional properties of the sensor. Due to high chemical resistance, gold (99.99%) is used as the wire material. The wire diameter of 17.5 μm was chosen for realization.

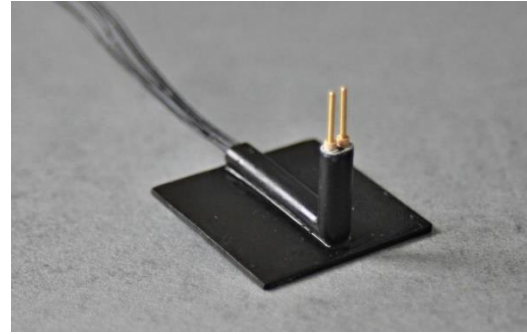


Figure 3 Sensor prototype

## VERIFICATION OF THE SENSOR'S PROPERTIES

For the verifying the characteristics of the sensor (Fig. 4), it is of primary importance that the structure is functioning without damage under the given operating conditions. However, the most important findings are specific technical characteristics such as range of function, sensitivity or critical operating conditions. The JBS JTSE hot air soldering station was used for a basic experiment to verify sensor properties. It is sufficient by the range of adjustable temperatures (150-450 ° C) but also by the range of flowing air volume (5-50 SLPM). [6]

The specified volumetric flow rate corresponds to an air velocity range of 0.7-7.3 m / s.

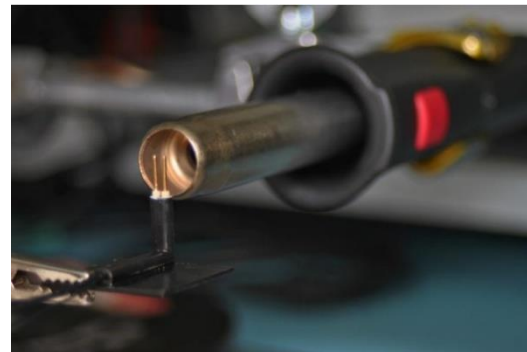


Figure 4 Detail of using the experimental sensor

The four-point probe method with a DC operating current of 600 mA was used to measure changes in sensor resistance. [3]

This current is sufficient to heat the wire to about 900 ° C. To achieve the highest sensitivity, it is necessary to heat the wire to the highest possible temperature but not too high to prevent the wire loop from melting. The experiment determined that the used wire would melt at current in the range of 680-720 mA at 23 ° C (Fig. 6). This range depends on the environment temperature and the length of the wire itself. For the measuring of the sensor's properties was used the soldering station. The sensor was placed in fixed position at the distance of 3 mm from the exhaust of the hot air station (Fig. 5).

The measurement was started at a volumetric flow rate of 5 SLPM for temperatures up to 300 °C. Subsequent increase of the volumetric flow resulted in a gradual linear decrease of the sensor resistance in all measured cases (Fig. 7).

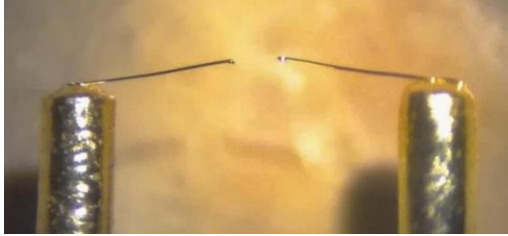


Figure 6 Damaged wire

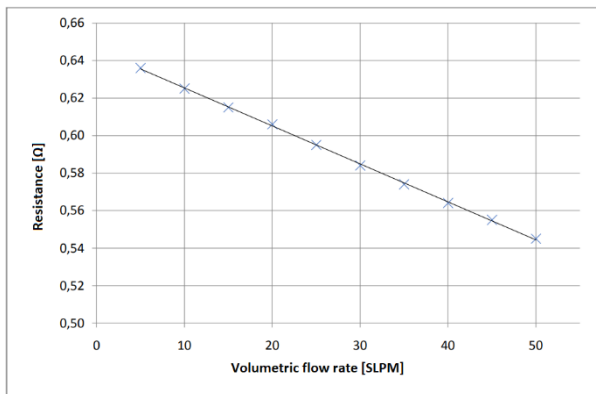


Figure 7 Change in sensor resistance depending on volumetric flow rate ( $t_{air} = 300\text{ }^{\circ}\text{C}$ )

Directional sensitivity was another monitored property. In the case of a single-wire sensor, where is only one direction measurement used, is this parameter not important. However, in spatial measurement with a multi-wire sensor, this parameter is crucial for the accuracy of the speed measurement and the accuracy of the direction of the flow source. For a future application of wire-bonding technology in this area of anemometry, this work also includes a characteristic of the directional sensitivity of the sensor. This measurement was performed at a volumetric flow rate of 17.5 SLPM which is approximately 2.5 m / s (Fig. 8).

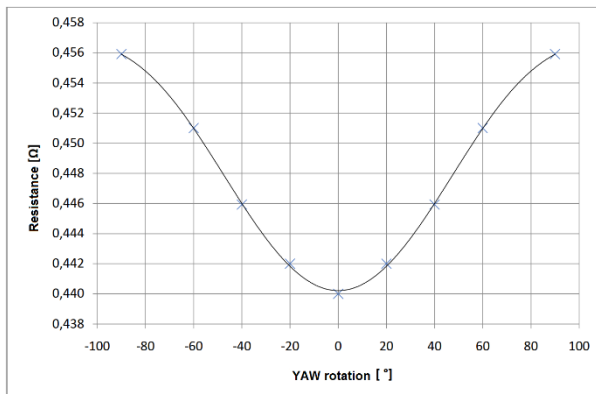


Figure 8 YAW characteristic ( $t_{air} = 150\text{ }^{\circ}\text{C}$ )

From the measured results it can be concluded that the designed sensor can respond to changes in the flow direction. This characteristic depends not only on the rotation of the sensor relative to the flow source but also on the temperature of the flowing air and its velocity. The sensor is more sensitive when the flow rate is increased or the air temperature is lower. It will be important to choose the correct measurement method, which will ensure sufficient sensitivity of the measurement. To use this phenomenon, it is necessary to follow the correct procedure and design of the wire connection by wire-bonding technology. In the case of imperfect flatness of the microwire, the loop may occur distortion, a decrease of sensitivity, or change in directional symmetry.

Multipurpose using of the experimental sensor is also possible, but it is necessary to change the setting of the  $I_{sens}$  measuring current. At a low current that the wire is not heating, it is possible to measure the changes in the electrical resistance of the wire. This change is added to the change in the ambient temperature. The use of the sensor is possible not only for measuring of flow velocity but also for measuring temperature. This property was verified experimentally using the JBS JTSE hot air station. When the temperature of the flowing air increased, the sensor's electrical resistance increased linearly too. (Fig. 9).

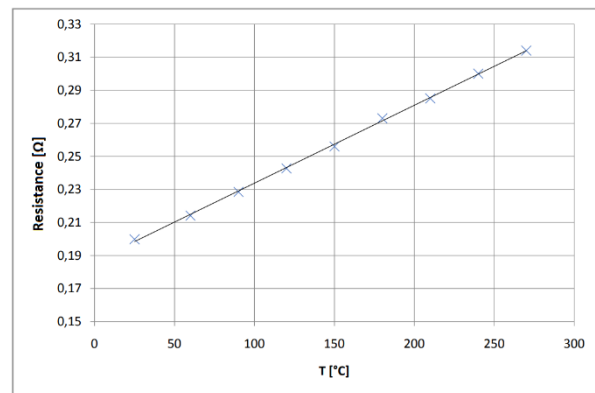


Figure 9 Change in sensor resistance depending on environment temperature ( $I_{sens} = 10\text{ mA}$ )

## APPLICATION USE

Based on the function of the sensor and its measured properties it is possible to consider its further application. There are applications for which similar sensors are intended, i.e. ventilation or air-conditioning equipment or other industries areas where ventilation ducts are used. In the science laboratory areas or manufacturing industries, the sensor is also usable for checking the functionality and flow velocity of the air in ducts. The measurement can be realized in an environment where are hazardous or corrosive substances due to durable materials used for the construction of the sensor. The sensor is designed for short-term measuring with a speed of airflow up to 10

m / s with a sensitivity of 0.1 m / s. Also, the materials and design used, allow the sensor to be used up to 300 ° C. Other areas of application may be dryers, brazing ovens or small assembly stations.

## CONCLUSION

Based on the experiment, it can be stated that wire-bonding technology can be used in the field of hot anemometry as an alternative to currently used technologies. This study deals with the prototype that used wire of gold (99.99%) with a diameter of 17.5 µm. Using a larger diameter would reduce sensor sensitivity and would extend signal response. Smaller diameters may not have sufficient mechanical strength. The prototype uses two general operating currents. The 600 mA current to measure airflow changes and 10 mA current to measure temperature changes. The experiment confirmed the fundamental theoretical assumptions of the behavior for the gold micro-wire. The changes in resistance are sufficient for the evaluation of the measurements. Increasing of the environment airflow results in the linear decreasing of the electrical resistance of the sensor over the full measuring range. The basic condition for the proper functioning of the sensor is sufficient heating of the wire to the high temperature. The higher the temperature difference between the anemometer wire and the flowing air is, the sensor is more sensitive. For the possible application or next experiments in the future, it is recommended to consider the use of beryllium or palladium alloy with gold wire to improve the mechanical strength of the sensor wire.

## ACKNOWLEDGMENT

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